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THE

MANURES

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VARIOUS KINDS OF SOILS,

AND THE CAUSES

OF

THEIR BENEFICIAL EFFECT

IN EACH PARTICULAR INSTANCE.

.....Idoneus Patriæ, sit Utilis Agris.
Juv. Sat. 14.

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BY

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WHAT ARE THE MANURES MOST ADVANTAGEOUSLY APPLICABLE TO THE VARIOUS SORTS OF SOILS;

AND,

WHAT ARE THE CAUSES OF THEIR BENEFICIAL EFFECT IN EACH PARTICULAR INSTANCE.

..... Idoneus Patriæ, sit Utilis Agris.
JUVEN. SAT. 14.

AGRICULTURE is the art of making the earth produce the largest crop of useful vegetables at the smallest expense. It has often been remarked, that amidst the various improvements which most of the practical arts have derived from the progress lately made in natural philosophy and chemistry, none have fallen to the share of agriculture, but that it remains nearly in the same state in which it existed two thousand years ago. I am far from allowing the truth of this observation, taken

in its totality ; to refute it, we need only compare the writings of Cato, Columella, or Pliny, with many modern tracts, or still better, with the modern practice of our best farmers. It must be granted, however, that vague and fortuitous experience has contributed much more to the present flourishing state of this art than any general principles deduced from our late acquired knowledge, either of the process of vegetation, or of the nature of soils ; but the skill thus fortuitously acquired is necessarily partial, and generally local ; the very terms employed by the persons who most eminently possess it, are generally of a vague and uncertain signification. Thus Mr. Young, to whose labours the world is more indebted for the diffusion of agricultural knowledge than to any writer who has as yet appeared, remarks, That in some parts of England, where husbandry is successfully practised, any loose clay is called marl* ; in others, marl is called chalk† ; and, in others, clay is called loam ‡. Philosophic researches have been made, but not yet sufficiently noticed: much information may be derived from Monsieur Du Hamel, and much more from the well-directed experiments of

* First Eastern Tour, 178.
† 2 Bath Mem. 192, 220. ‡ 2 Bath Mem. 137.

Mr. Tillet*. Immense strides have been made in this career, by the illustrious Bergman; Dr. Priestley's experiments have thrown a new light on this, as well as on every other object of natural philosophy. Mr. Lavoisier's new theory explains many circumstances, before inexplicable; discoveries of great importance have been made by Mr. Senebier and Dr. Ingenhouz: even Mr. Young has not always confined his attention to the mere practical part, but sometimes happily extended it to objects of a more general and speculative nature; but the fullest light, perhaps, has been thrown on this subject by the late discoveries of Mr. Hassenfraz.†

If the exact connexion of effects, with their causes, has not been so fully and so extensively traced in this as in other subjects, we must attribute it to the peculiar difficulties of the investigation. In other subjects, exposed to the joint operation of many causes, the effect of each, singly and exclusively taken, may be particularly examined; the experimenter may work in his laboratory with the object always in his view; but the secret processes of vegetation take place in the dark, exposed to the various and indeterminable influences of

* Mem. Par. 1772. † Annales Chymiques, Vol. 13, 14.

the atmosphere, and require, at least, half a year for their completion. Hence the difficulty of determining on what peculiar circumstance success or failure depends; the diversified experience of many years can alone afford a rational foundation for solid specific conclusions. It cannot therefore, be expected, that new, decisive, and direct experiments should be laid before the Academy within the time prescribed for answering this question. The resolution of the first part must be deduced from a statement of facts long established by multiplied experience; and that of the second, by the application of more general principles to the explanation of those facts.—But before we proceed to either branch of this question, the distinctions and denominations, both of soils and manures, must be exactly settled and accurately defined.

CHAP. I.

OF SOILS AND MANURES.

SECTION I.

OF SOILS.

LAND, considered as the basis of vegetation, is called *soil*.

Soils consist of different combinations of two or more of the four primitive earths, namely, the calcareous (which I sometimes call mild calx) magnesia, argill, and the silicious. For a more accurate description of these I must refer to books of mineralogy; and shall only remark, that by calcareous earths are meant chalk, and all stones that burn to lime. They are easily distinguished by their property of effervescing with acids.

Magnesia is never found alone; its distinguishing character consists in affording a bitter salt, generally called Epsom Salt, when combined with the vitriolic acid.

Argill is that part of clay to which this owes its property of feeling soft and unc-

tuous, and of hardening in fire; it is difficultly soluble in acids, and scarce ever effervesces with them. When combined with the vitrolic acid, it forms alum.

Silicious Earth is often found in a stony form, such as flint or quartz; and still more frequently in that of a very fine sand, such as that whereof glass is made. It does not effervesce, nor is it soluble in any of the common acids.

To these we may add Iron, in that imperfect state in which it exists when reduced to rust, and commonly called Calx of Iron.

The soils most frequently met with, and which deserve a distinct consideration, are clay, chalk, sand, and gravel, clayey loam, chalky loam, sandy loam, gravelly loam, ferruginous loam, boggy soil, and heathy soil, or mountain, as it is often called.

Clay is of various colours; for we meet with white, grey, brownish red, brownish black, yellow or bluish clays; it feels smooth, and somewhat unctuous: if moist, it adheres to the fingers, and if sufficiently so, it becomes tough and ductile. If dry, it adheres more or less to the tongue: if thrown into water, it gradually diffuses itself through it, and slowly separates from it. It does not usually effervesce with acids, unless a strong heat be applied, or

that it contains a few calcareous particles, or magnesia. If heated, it hardens and burns to a brick.

It consists of argill and fine sand, usually of the silicious kind, in various proportions, and more or less ferruginous. The argill forms generally from 20 to 75 per cwt. of the whole mass; the sand and calx of iron the remainder. These are perfectly separable by boiling in strong vitrolic acid.

Chalk, if not very impure, is of a white colour, moderate consistence, and dusty surface, stains the fingers, adheres slightly to the tongue, does not harden when heated, but, on the contrary, in a strong heat burns to lime, and loses about four-tenths of its weight. It effervesces with acids, and dissolves almost entirely therein. I shall also add, that this solution is not disturbed by caustic volatile alkali, as this circumstance distinguishes it from magnesia,—it promotes putrefaction.

Sand. By this is meant small loose grains of great hardness, not cohering with water, nor softened by it. It is generally of the silicious kind, and therefore insoluble in acids.

Gravel differs from sand chiefly in size: however stones of a calcareous nature,

when small and rounded, are often comprehended under that denomination.

Loam denotes any soil moderately cohesive: that is, less so than clay, and more so than loose chalk. By the author of the Body of Agriculture, it is said to be a clay mixed with sand. Doctor Hill defines it an earth composed of dissimilar particles, hard, stiff, dense, harsh, and rough to the touch, not easily ductile while moist, readily diffusible in water, and composed of sand and a tough viscid clay. The definition I have given seems most suited to the different species I shall now enumerate.

Clayey Loam denotes a compound soil, moderately cohesive, in which the argillaceous ingredient predominates. Its coherence is then greater than that of any other loam, but less than that of pure clay. The other ingredient is a *coarse* sand, with or without a small mixture of the calcareous ingredient. It is this which farmers generally call *strong*, *stiff*, *cold*, and *heavy* loam, in proportion as the clay abounds in it.

Chalky Loam. This term indicates a loam formed of clay, coarse sand, and chalk; in which, however, the calcareous ingredient or chalk much predominates. It is less cohesive than clayey loams.

Sandy Loam denotes a loam in which

sand predominates : it is less coherent than either the abovementioned. Sand, partly coarse and partly fine, forms from 80 to 90 per cent. of this compound.

Gravelly Loam differs from the last only in containing a larger mixture of coarse sand, or pebbles. This and the two last are generally called, by farmers, *light* or *hungry* soils ; particularly when they have but little depth.

Ferruginous Loam, or *Till*. This is generally of a dark brown, or reddish colour, and much harder than any of the preceding : it consists of clay and calces of iron, more or less intimately mixed. It may be distinguished not only by its colour, but also by its superior weight : it sometimes effervesces with acids, and sometimes not ; when it does, much of the irony part may be separated, by pouring it, when well dried, into spirit of salt ; from which the iron may afterwards be separated by alkalis or chalk.

——Akin to this are certain *vitriolic soils*, which, when steeped in water, impart to it the power of reddening syrup of violets. These are generally of a blue colour, but redden when heated.

Boggy Soil or *Bogs*, consist chiefly of ligneous roots of decayed vegetables mix-

ed with earth, mostly argillaceous, and sand, and a coally substance derived from decayed vegetables. Of bogs there are two sorts : the black, which contain a larger proportion of clay and of roots more perfectly decayed, with mineral oil. In the red the roots seem less perfectly decayed, and to form the principal part.

Heathy Soil is that which is naturally productive of heath.

SECTION II.

OF MANURES.

Manure denotes any substance or operation by which a soil is improved. To improve a soil is to render it capable of producing corn, legumens, and the most useful grasses.

The substances principally used as manures, are chalk, lime, clay, sand, marl, gypsum, ashes, stable-dung, mucks, farm-yard dung, pounded bones, sea-weeds, sweepings of ditches, old ditches. Other manures or top-dressings, as they are employed chiefly to promote the growth of vegetables, and not merely with a view of improving the soil, I omit.

The operations used to improve soils, are fallows, draining, paring and burning.

Of chalk, clays, and sand, we have already treated.

Lime is a substance whose external characters and mode of production are well known. It differs from chalk and powdered limestone chiefly by the absence of fixed air, which is expelled from these during their calcination. This air it gree-

dily re-absorbs from the atmosphere, and all other bodies with which it comes in contact, and which can furnish it; but it cannot unite with the air unless it is previously moistened. 100 parts quick-lime absorb about 28 of water. It is soluble in about 700 parts of this fluid. To regain its full portion of air from the atmosphere, it requires a year or more, if not purposely spread out: it resists putrefaction; but with the assistance of moisture, it resolves organic substances into a mucus.

Marl is of three sorts; calcareous, argillaceous, and silicious or sandy. All are mixtures of mild calx (*i. e.* chalk) with clay, in such a manner as to fall to pieces by exposure to the atmosphere more or less readily.

Calcareous Marl is that which is most commonly understood by the term *Marl*, without addition. It is generally of a yellowish white, or yellowish grey colour; rarely brown or lead coloured. It is seldom found on the surface of land, but commonly a few feet under it, and on the sides of hills, or rivers that flow through calcareous countries, or under turf in bogs. Frequently of a loose texture, sometimes moderately coherent; rarely of a stony hardness, and hence called *stone-marl*. Sometimes of a compact, sometimes of a

lamellar texture; often so thin as to be called *paper-marl.* It often abounds with shells, and then is called *shell-marl;* which is looked upon as the best sort. When in powder, it feels dry between the fingers; put in water, it quickly falls to pieces or powder, and does not form a viscid mass. It chips and moulders by exposure to the air and moisture, sooner or later, according to its hardness and the proportion of its ingredients: if heated, it will not form a brick, but rather lime. It effervesces with all acids. It consists of from 33 to 80 per cent. of mild calx, and from 66 to 20 per cent. of clay.

To find its composition, pour a few ounces of weak, but pure spirit of nitre, or common salt, into a Florence flask; place them in a scale, and let them be balanced; then reduce a few ounces of dry marl into power, and let this powder be carefully and gradually thrown into the flask, until after repeated agitation no effervescence is any longer perceived; let the remainder of the powdered marl be then weighed, by which the quantity projected will be known; let the balance be then restored; the difference of weight between the quantity projected and that requisite to restore the balance will dis-

cover the weight of air lost during effervescence ; if the loss amounts to 13 per cwt. of the quantity of marl projected, or from 13 to 32 per cwt. the marl essayed is calcareous marl. This experiment is decisive, when we are assured by the external characters above mentioned, that the substance employed is marl of any kind ; otherwise some sorts of the sparry iron-ore may be mistaken for marl. The experiments to discover the argillaceous ingredient (being too difficult for farmers) I omit. The residue left after solution, being well washed, will, when duly heated, generally harden into a brick.

Argillaceou Marl contains from 68 to 80 per cent. of clay, and consequently from 32 to 20 per cent. of aerated calx. Its colour is grey or brown, or reddish brown, or yellowish or bluish grey. It feels more unctuous than the former, and adheres to the tongue : its hardness generally much greater. In water it falls to pieces more slowly, and often into square pieces : it also more slowly moulders by exposure to the air and moisture, if of a loose consistence : it hardens when heated, and forms an imperfect brick. It effervesces with spirit of nitre or common salt, but frequently refuses to do so with vine-

gar. When dried and projected into spirit of nitre, in a Florence flask, with the attentions above-mentioned, it is found to lose from 8 to 10 per cwt. of its weight. The undissolved part, well washed, will, when duly heated, harden into a brick.

Silicious, or *Sandy Marls*, are those whose clayey part contains an excess of sand: for, if treated with acids in the manner above-mentioned, the residuum, or clayey part, will be found to contain above 75 per cwt. of sand; consequently chalk and sand are the predominant ingredients.

The colour of this marl is brownish gray, or lead coloured: generally friable and flakey, but sometimes forms very hard lumps. It does not readily fall to pieces in water. It chips and moulders by exposure to the air and moisture, but slowly. It effervesces with acids; but the residuum, after solution, will not form a brick.

Limestone-Gravel. This is a marl mixed with large lumps of limestone. The marl may be either calcareous or argillaceous; but most commonly the former. The sandy part is also commonly calcareous.

Gypsum is a compound of calcareous earth and vitrolic acid: it forms a distinct species of the calcareous genus of fossils: of which species there are six families.

The general character of this species are,

1. *Solubility* in about 500 times its weight of water, in the temperature of 60°.

2. *Precipitability* therefrom by all mild alkalis, and also by caustic fixed, but not by caustic volatile alkali.

3. *Ineffervescence* with acids, if the gypsum be pure; but some families of this species, being contaminated with mild calx, slightly effervesce.

4. *Insolubility*, or nearly so in the nitrous acid, in the usual temperature of the atmosphere.

5. *A specific gravity*, reaching from, 2,16 to 2,31.

6. A degree of *hardness*, such as to admit being scraped by the nail.

7. When heated nearly to redness, it calcines; and if then it be slightly sprinkled with water, it again concretes and hardens.

8. It promotes putrefaction in a high degree.

Of the six families of this species I shall describe only one; namely, that which

has been most advantageously employed as a manure. Descriptions of the other five should be found in treatises of mineralogy. It is called *fibrous gypsum.*

Its colours are gray, yellowish or reddish, or silvery white, or light red, or brownish yellow, or striped with one or more of these dark colours. It is composed of fibres or striæ, either straight or curved, parallel or converging to a common centre, sometimes thick, sometimes fine and subtile, adhering to each other, and very brittle: its hardness such as to admit being scraped with the nail: commonly semi-transparent; in some, often in a high degree.

Ashes. Sifted coal-ashes, those of peat and white turf-ashes, have been found useful; red turf ashes useless, and generally hurtful. Wood-ashes have also been employed advantageously in many cases; they contain either the four primitive earths, as Mr. Bergman asserts; or calcareous earth chiefly, according to Achard; or calcareous and magnesia, according to D'Arcet. They also contain some proportion of phosphorated selenite, *i. e.* calcareous earth united to the phosphoric acid. Almost all contain also a small and variable proportion of common salt, Glau-

ber's salt, and terrene salts, which, when in a small dose, all accelerate putrefaction; also small bits of charcoal.

Charcoal is a substance well known; it has frequently and successfully been used as a manure. 1st Young's Annals, 152, &c. &c.

Soap-boilers Waste forms an excellent manure for some soils; it contains, by Mr. Ruckert's Analysis, 57 per cwt. of mild calx, 11 of magnesia, 6 of argill, and 21 of silex

Stable Dung. This is used either fresh or putrefied; the first is called *long*, the other *short dung*; it abounds in animal matter, easily runs into putrefaction, and when putrefied serves as a leaven to hasten the decay of other dead vegetable substances; its fermentation is promoted by frequent agitation and exposure to the air; yet it should be covered to prevent water from carrying off most of its important ingredients; or at least the water that imbibes them should not be lost.

Farm-yard Dung consists of various vegetables; as straw, weeds, leaves, fern, &c. impregnated with animal matter; it ferments more slowly than the former:

should be piled in heaps, and stirred, from time to time. Fern putrefies very slowly. The water that issues from it should be preserved.

Some of these manures have been analysed.

TABLE OF CONTENTS OF MANURES.

105 lb.	Heavy Inflam. Air. Cub. In.	Fixed Air. Cub. In.	Water lb.	Coal. lb.	Calx and Magnesia. lb.	Argill lb.	Silex lb.	Vol. Alk. lb.	Fixed Salts. lb.
Fresh Cow-dung*	—	—	—	3,75	1, 2	0,15	2, 4	—	0, 6
Fresh Horse-dung*	—	—	88	10,2	1, 5	0,5	3	—	0,21
Sheeps dung*	—	—	—	25,0	9,2 8 Calx 1, Mag.	3	29	—	0,72
Rotten Cow-dung*	1360	120	81 Water and Oil	10	3.	0, 6	5	0,65	Gyps. 0, 9 F. Salts. 0,24
Earth resulting from rotten Horse-dung†	1,64	1.	38,15	18,75	6, 2	1, 5	23,43		
Soap-boilers Waste*	—	—	—	—	57 Calx 11 Mag.	6,	21		

* 2 Ruckert.

† In Encyclopæd. Art. Vegetation. *Hassenfraz.*

Hence they should be applied, not indiscriminately, but according to circumstances, to be indicated in the sequel.

Pounded bones form also manure much used in the neighbourhood of great towns. They gradually deposit their oily part, which contains a large proportion of animal coal which is extricated by putrefaction, and phosphorated calx. Hence Bone-ash is also useful.

Sea-weed, particularly if mixed with earth, soon putrefies, and makes a good manure.

Sweepings of Ditches abound with putrid matter from decayed vegetables, and hence form a manure.

Old Ditches, exposing a large surface to vegetation, contain, when destroyed, a quantity of decayed vegetables, which putrefy and make a good manure ; but in this and the former case, it may be proper to distinguish of what soil they are composed, for reasons that will hereafter appear.

Fallowing, is the principal operation by which exhausted lands are restored to fertility ; its use seems to me to consist in exposing the roots of vegetables to decay, whereby food for a fresh growth is pre-

pared ; the atmosphere also deposits fixed air and carbonaceous substance on earth long exposed to it.

Draining is an operation equally necessary and well known, on which no more need be said here.

Paring and burning reduces the roots of vegetables to coal and ashes ; and thus prepares both a stimulant and nutriment for plants, as will be seen hereafter.

CHAP. II.

OF THE FOOD OF PLANTS, AND THE COMPOSITION OF FERTILE SOILS.

HAVING, in the preceding chapter, explained the nature of the different soils known in agriculture, and of the different manures whose general utility has been ascertained by long experience, we are now to inquire which of those manures are most advantageously applicable to each of those particular soils, and what are the causes of their beneficial effect in each particular instance.

To proceed with order in this inquiry, we must observe, that the general effect expected from the application of manure is fertility; that is, the most copious production of corn and grasses; and, since fertility is itself the result of the due administration of the food of those vegetables, we must first see what that food is, and of what ingredients a soil ought to be composed, in order to contain or administer it; after which we shall indicate by

what manures each particular sort of soil is brought into a fertile state (which is the beneficial effect expected from them) and how in each particular case they contribute to the due adminstration of the vegetable food, which is the cause of their beneficial effect.

SECTION I.

OF THE FOOD OF PLANTS.

To discover the food of plants, particularly of those which form the object of our present inquiry, we must examine the nature and proportion of the substances in which they grow, and of those which they themselves contain : thus we shall be enabled to see which of the latter are derived from the former.

First, All plants (except the subaqueous) grow in a mixed earth, moistened with rain and dew, and exposed to the atmosphere. If this earth be chemically examined, it will be found to consist of silicious, calcareous, and argillaceous particles, often also of magnesia, in various proportions, a very considerable quantity of water, and some fixed air. The most fertile, also, contain a small proportion of

oil, roots of decayed vegetables, a coaly substance arising from putrefaction, some traces of marine acid, and gypsum.* On the other hand, if vegetables be analysed, they will be found to contain a large proportion of water and charcoal; also fat and essential oils, resins, gums, and vegetable acids: all which are reducible to water, pure air, inflammable air and charcoal: a small proportion of fixed alkali is also found, some neutral salts, most commonly gypsum, tartar, vitriolate, common salt, and salt of sylvius. In corn, and particularly wheat, phosphorated selenite is also found.

Hence we see that, on the last analysis, the only substances common to the growing vegetables and the soils in which they grow, are water, coal, different earths, and salts. These, therefore, are the true food of vegetables: to them we should also add fixed air, though, by reason of its decomposition, it may not be distinctly found in them, or at least not distinguishable from that newly formed during *their decomposition.*

I shall now examine the separated functions of each of these ingredients.

* Home, 15 Mem. D'Agriculture, Par. 1790. Encyclopæd. *Vegetation*, p. 277.

OF WATER.

The agency of water in the process of vegetation, has never been doubted, though the manner in which it contributes to it has not, until of late, been distinctly perceived. Doctor Hales has shewn, that in the summer months a sun-flower weighing three pounds avoirdupois, and regularly watered every day, passed through it, or perspired, 22 ounces each day; that is, nearly half its weight. He also found that a cabbage plant, weighing 1 lb. 9 oz. sometimes perspired 1lb. 3 oz.; but at a medium about half its weight.* Doctor Woodward found that a sprig of common spearmint, a plant that thrives best in moist soils, weighing only 28,25 grs. passed through it 3004 grs. in 77 days, between July and October; that is, somewhat more than its own weight each day. He did more; for he found that in that space of time the plant increased 17 grs. in weight, and yet had no other food but pure rain water. But he also found that it increased more in weight when it lived on spring-water, and still more when its food was Thames water†. From whence

* 1 Hales, 9, 10, 15. † 2 Phil. Trans. Abr. 716.

we may deduce, that grasses and corn, during the time of their growth, absorb about one half their weight of water each day, if the weather be favourable.

Secondly, that the water they thus pass nourishes them merely as water, without taking any foreign substance into the account: for 3000 grs. of rain water, in Doctor Woodward's experiment, afforded an increase of 17 grains; whereas, by Margraaff's experiments, 5760 grs. of that water contain only one third of a grain of earth*. But,

Thirdly. It also follows, that water contributes still more to their nourishment when it conveys to them earthy and saline particles, as spring and Thames waters do.

The manner in which pure water contributes to the nourishment of plants, besides the service it renders them in distributing the nutritive parts throughout their whole structure, and forming itself a constituent part of all of them, may be understood from modern experiments. Doctor Ingenhouz and Mr. Senebier have shewn that the leaves of plants exposed to the sun produce pure air: now water

* 2 Margr. 6, 70.

has of late been proved to contain about 87 per cwt. of pure air, the remainder being inflammable air. Water is then decomposed by the assistance of light within the vegetable; its inflammable part is employed in the formation of oils, resins, gums, &c. its pure air is partly applied to the production of vegetable acids, and partly expelled as an excrement.

Many, indeed, have asserted, that water is the sole food of vegetables; and among the experiments adduced to prove it, that of Van Helmont, quoted by the illustrous Mr. Boyle*, is by far the most specious. He planted a trunk of willow, weighing 5lb. in an earthen vessel filled with earth dried in an oven, and then moistened with rain-water. This vessel, it appears, he sunk in the earth, and watered partly with rain-water, and occasionally with distilled. After five years he found the tree to weigh 169 lb. and the earth in which it was planted, being again dried, to have lost only 2 oz. of its former weight, though the tree received an increase amounting to 164 lb.

Before I proceed to the explication of this experiment, I must remark some cir-

* 2d Shaw's Boyle, 240.

cumstances attending it: First, that the weight of the earth contained in the vessel at the commencement and at the end of five years, could not be exactly compared, because the same degrees of desiccation could not be exactly ascertained, and because many of the fibrillæ of the roots of the tree must have remained in the earth after the tree was taken out of the vessel, and these must have prevented the true loss of earth from being perceived. Secondly, That the earthen vessel must have frequently absorbed water impregnated with whatever substance it might contain, from the surrounding earth in which it was inserted; for unglazed earthern vessels easily transmit moisture. (1st Hales 5, and Tillet's Mem. Par. 1772, page 298, 304, 8vo.) Thirdly, As it appears that the pot was sunk in the earth, and received rain-water, it is probable that distilled water was seldom used.

These circumstances being considered, it will easily be made to appear that the rain-water, absorbed by the tree, contained as much earth as the tree can be supposed to contain.

First, The willow increased in weight 164 lb. in five years; that is, at the rate of 2,7 lb. nearly per month; and it being an

aquatic, it cannot be supposed to pass less than its own weight of water each day during the six vegetating months. In the first month, therefore, it absorbed and passed $5 \times 30 = 150$ lb. and as each pound of rain-water contains $\frac{1}{3}$ gr. of earth, 50 grains of earth must have been deposited in the plant; and allowing no more than 50 grains for the deposit of each of the six months, we shall have $50 \times 6 = 300$ for the deposit of the first year: but at the end of the first year the plant gains an accession of the 32lb. therefore, in each of the six summer months of the succeeding year, it passes $37 \times 30 = 1110$ lb. of water, and receives a deposit of 370 grains; and at the end of the second year the deposit amounts to 2220 grains. At the commencement of the third year, the tree gaining a farther accession of 32 lb. must weigh 69 lb. and pass in each of the summer months $69 \times 30 = 2070$ lb. of water, and receive a deposit of 690 grs. which multiplied into $6 = 4140$ grains. At the commencement of the fourth year, the tree still gaining 32 lb. must weigh 101 lb; and if it passes 101×30 in each of the summer months, it must gain a deposit in each of 1010 grs. of earth, and at the end of the year, 6060.

At the commencement of the fifth year it weighs 133 lb. and gains at the end of the six months 23940 grains of earth. The quantities of earth deposited each year exceed 5 lb. avoirdupois, a quantity equal to that which 169 lb. of willow can be supposed to contain; for the commissioners employed to inspect the fabrication of saltpetre in France, having examined the quantities of ashes afforded by trees of various kinds, found that 1000 lb. of sallow, a tree much resembling the willow, afforded 28 lb. of ashes, and consequently 169 lb. should produce 4,7. I do not give this calculation, however, as rigorously exact. It is certain, that if the deposit left at the end of every month were exactly taken, the total would exceed the quantity just mentioned; but that, found even by this rude mode, sufficiently proves that water conveys a portion of earth into vegetables equal to any that the experiments hitherto made can prove to exist in them.

As to the coal, or carbonaceous principle, which this willow must also have contained, it is probable that much of it existed in the earth in which the willow grew. Some is contained in all moulds or

vegetable earth; and as we are not told what sort of earth Van Helmont used, we may well suppose it was good vegetable earth, its quantity amounting to 200 lb. This principle may also have been contained in the water, for the purest rain-water contains some oleaginous particles, though in an exceeding small proportion, as Mr. Margraaff has observed*; and all oil contains coal. Some also may have passed from the surrounding vegetable earth through the pores of the earthen vessel. All the other experiments, adduced to prove that water is the sole food of plants, may be explained in the same manner. Grains of wheat have been made to grow on cotton moistened with water; each produced an ear, but that ear contained but one grain †. Here the carbonaceous substance was derived from the grain, and afterwards diffused and transported through the whole plant by the water absorbed; for it must be observed that grain, like an egg, contains much of the nourishment of its future offspring. It is thus that tulips, hyacinths, and other plants, expand and grow in mere water.

The earth contained in rain-water is

* 2d Margr. 15,90. † 2d Young's Annals, 487.

united partly with the nitrous and marine acids, as Margraaff has shewn, but far the greater part only with fixed air; for the feeble traces of the two former acids could not hold in solution the 100 grains of earth which he found in 300 lb. of rain-water.

By far the greatest proportion of vegetable substances consist of water. According to Mr. Young and Ruckert, grass loses about 2-thirds of its weight on being dried into hay*. Dr. Hales found a sun-flower plant, which weighed 48 ounces, to lose 36 ounces by drying in the air during thirty days†, and consequently to have lost 3-fourths of its weight. Even vegetables to appearance thoroughly dry, contain from 3-fifths to 3-fourths of their weight of water‡. This water is not all in a liquid state, but, by the loss of much of its specific heat, is in a great measure solidified.

* 2d Young's Ann. 26. 2d Ruck. 139.
† 1st Hales, 8.
‡ Ruckert, 28. Sench. Encyclop. *Vegetation*. 52.

OF COAL, OR THE CARBONIC SUBSTANCE.

To Mr. Hassenfraz we owe the discovery, that coal is an essential ingredient in the food of all vegetables. Though higherto little attended to, it appears to be one of the primæval principles, as ancient as the present constitution of our globe: for it is found in fixed air, of which it constitutes above one-fourth part; and fixed air exists in lime-stones and other substances, which date from the first origin of things.

Coal not only forms the residuum of all vegetable substances that have undergone a slow and smothered combustion, that is, to which the free access of air has been prevented, but also of all putrid vegetable and animal bodies: hence it is found in vegetable and animal manures that have undergone putrefaction, and is the true basis of their ameliorating powers: if the water that passes through a putrefying dunghill be examined, it will be found of a brown colour; and if subjected to evaporation, the principal part of the residuum

will be found to consist of coal*. All soils steeped in water communicate the same colour to it in proportion to their fertility; and this water being evaporated, leaves also a coal, as Mr. Hassenfraz and Fourcroy attest†. They also observed, that shavings of wood being left in a moist place for nine or ten months, began to receive the fermentative motion, and being then spread on land, putrefied after some time, and proved an excellent manure‡. Coal, however, cannot produce its beneficial effects but in as much as it is soluble in water. The means of rendering it soluble are not as yet well ascertained; nevertheless, it is even now used as a manure, and with good effect§. In truth, the fertilizing power of putrid animal and vegetable substances were fully known even in the remotest ages, but most speculatists have hitherto attributed them to the oleaginous, mucilaginous, or saline particles then developed, forgetting that land is fertilized by *paring* and *burning*, though the oleaginous and mucilaginous particles are thereby consumed or reduced to a coal, and that the quantity of mucilage, oil or salt in fertile land is so small, that it could

* 14 Ann. Chym. 56. † Ibid.
‡ Ibid. § Young's Annals.

not contribute the 1000th part of the weight of any vegetable; whereas coal is supplied not only by the land, but also by the fixed air combined with the earths, and also by that which is constantly set loose by various processes, and soon precipitates by the superiority of its specific gravity, and is then condensed in, or mechanically absorbed by, soils, or contained in dew. Lands which contain iron in a semicalcined state, are thereby enabled to decompose fixed air, the iron, by the help of water, gradually attracting the pure air, which enters into the composition of fixed air, as Mr. Gadolin has shewn*: a discovery which appears to me among the most important of these later times; but these calces of iron may again be restored to their former state by union with oleaginous substances, as Mr. Beaume has noticed; and this is one of the benefits resulting from the application of dung before it has fully putrefied†. Hence we may understand how soils become effected and exhausted, this effect arising, in great measure, from the gradual loss of the carbonic principle deposited by vege-

* 1st Chym. Ann. 1791, 53.

† The affinities of coal and iron to pure air, vary with the temperature.

table and animal manures, and from them passing into the growing vegetables; and also from the loss of the fixed air contained in the argillaceous part of the soil, which is decomposed by vegetables; and from the calcination of the ferruginous particles contained in the soil. I say *in great measure*, because other causes contribute to the diminution of fertility; which shall presently be mentioned. Hence, also, we see why lands pastured remain longer fertile than those whose vegetable crop is carried off, as much of the carbonaceous principle is restored by the excrements of the pasturing animals: why some crops exhaust more than others; because corn, and particularly wheat, contains more of the carbonic principle than grasses, and very little of its exuviæ are left behind: why fallows are of some use; as the putrefaction of the roots of weeds and the absorption of fixed air by clays, are thereby promoted: why vegetables thrive most in the vicinity of towns; because the carbonic principle is copiously dispersed by the smoke of the various combustibles consumed in inhabited places: why soot is so powerful a manure: why burning the clods of grassy land contributes so much to its fertility,

and then only when the fire is smothered and coal produced; besides many other agricultural phenomena, too tedious to relate: but I must not omit that the phosphoric acid is found in coal; and this enters into the composition of many vegetables.

The quantity of coal in vegetables is various, according to their various species, age, and degrees of perfection: wood and corn contain most, grasses least. Weigleb found dry beech-wood to contain one fifth of its weight of coal*. Westrumb found *trifolium pratense*, a sort of clover, to contain about one seventh. Hence, after water, it is the most copious ingredient in vegetables.

OF EARTHS.

The next most important ingredient to the nourishment of plants is earth: and of the different earths the calcareous seems the most necessary, as it is contained in rain-water: and, absolutely speaking, many plants may grow without imbibing any other. Mr. Tillet found corn would grow

* Uber die alkalis, p. 76.

in pounded glass*; Mr. Succow in pounded fluor spar, or ponderous spar, or gypsum†: but Tillet owns it grew very ill; and Hassenfraz, who repeated this experiment, found it scarcely grow at all when the glass or sand were contained in pots that had no hole in the bottom, through which other nutritive matter might be conveyed. It is certain, at least, from common experience, that neither grasses nor corn grow well either in mere clay, sand, or chalk; and that in vegetables that grow most vigorously, and in a proper soil, three or four of the simple earths are found. Mr. Bergman, on the other hand, assures us he extracted the four earths, the silicious, argillaceous, calcareous, and muriatic, in different proportions from the different sorts of corn‡. Mr. Ruckert, who has analysed most species of corn and grasses, found also the four above-mentioned earths in various proportions in all of them. Of his analysis I shall here give a specimen, comprehending, however, the calcareous and muriatic in the same column, as this last scarcely deserves particular notice:

* Mem. par. 1772, 301, 8vo.
† 1st Chym. Ann. 1784.
‡ 5 Bergman, 94, 98. Schæffer Works, &c. 172.

One hundred parts of the lixiviated ashes of

	contained of Silex.	Calx.	Argill.
Wheat	48pts.	37	15
Oats	68	26	6
Barley	69	16	15
Bere	65	25	10
Rye	63	21	16
Potatoes	4	66	30
Red Clover	37	33	30

Mr. Ruckert is persuaded that earth and water, in proper proportions, form the sole nutriment of plants; but Mr. Giobert has clearly shewn the contrary; for, having mixed pure earth of alum, silex, calcareous earth, and magnesia, in various proportions, and moistened them with water, he found that no grain would grow in them; but when they were moistened with water from a dunghill, corn grew in them prosperously*. Hence the necessity of the carbonic principle is apparent.

The absolute quantity of earth in vegetables is very small. Dr. Watson informs us that 106 avoirdupois pound =1696 ozs. of oak, being carefully burned, left but 19 ozs. of ashes; and from

* Encyclop. *Vegetation*, 274.

these we must deduct 1,5 for salt, then the earthy part amounts only to 17,5; that is, little more than one per cwt. The commissioners appointed to inspect the saltpetre manufactory, found nearly the same result; namely, 1,2 per cwt. in beech 0,453, and in fir only 0,003. Hence we need not wonder at trees growing among rocks where scarce any earth is to be seen: but in the stalks of Turkey-wheat, or maize, they found 7 per cwt. of earth, in sun-flower plant 3.7*; so that, upon the whole, weeds and culmiferous plants contain more earth than trees do. Mr. Westrumb found *trifolium pratense* to contain about 4,7 per cwt. of earth, of which 2 per cwt. was mild calx, nearly 2 more silex, 0,7 argill, together with a small proportion of phosphorated iron, calx of iron, and manganese†.

Since plants derive some proportion of earth from the soil on which they grow, we cannot be surpised that these soils should, at length, be exhausted by crops that are carried off; such as those of corn and hay, particularly the former: even lands pastured must at last be exhausted, as the excrements of animals do not re-

* See 3 Trans. Royal Irish Academy.
† 1st Chym. Ann. 187.

store the exact quantity that the animals have consumed ; and hence the utility of mucks, as the restoration is performed by more animals than have been employed in the consumption. Hence also a succession of different crops injures land less than a succession of crops of the same kind, as different proportions of the different earths are taken up by the different vegetables. Finally, we may hence derive the utility of marling land as the deficient earths are thereby replaced. This subject admits of more precision than has been hitherto imagined, and may even be subjected to calculation. The absolute quantity and relative proportions of the various earths in an acre of land may be determined, so may that in the crops of different vegetables ; and by comparing both, the *time* also may be found in which the land must be exhausted, unless renovated by various manures : thus the necessity of marling. The kind of marl or other manures, and the quantity necessary to an acre of land, may be very nearly ascertained.

Earths cannot enter into plants but in a state of solution, or at least only when suspended in water in a state of division as minute as if they had been really dissolv-

ed. That silicious earth may be suspended in such a state of division appears from various experiments, particularly those of Mr. Bergman, who found it thus diffused in the purest waters of Upsal; and it is equally certain that it enters copiously into vegetables. Both his experiments, and especially those of Mr. Macie, establish this point beyond contradiction*. Argillaceous earth may also be so finely diffused as to pass through the best filters; so also may calx, as appears from the quantity Margraaff found in the purest rainwater. This earth is even soluble by means of an excess of fixed air in about 1500 times its weight of water. It may also be, and most frequently is converted into gypsum by the vitriolic acid which most clays contain, as Mr. Morveau has shewn†, and then it is soluble in 500 times its weight of water.

Vegetables not only require food, but also that this food be duly administered to them; a surfeit is as fatal to them as absolute privation. Doctor Hales observed, that a young pear tree, whose roots were set in water, absorbed a smaller quantity of it every day, the sap-vessels being sa-

* Phil. Trans. 1791.

† 1st Encyclop. Chym. 123.

turated and clogged by it ; and Mr. Miller found that too much water rotted the young fibres of the roots as fast as they pushed out*. Saturated solutions of dung appeared to Mr. Du Hamel equally hurtful†. Now the preservation and due adminstration of this liquid food is effected by due proportions of the simple earths and their loose or condensed state. Their situation in other respects being the same, those that abound in the argillaceous principle are the most retentive of water ; those that abound in the coarse silicious, least ; the calcareous being intermediate between both ; various species of vegetables requiring various quantities of water and other food : hence it is that every sort of soil bears vegetables peculiarly adapted to it, while others do not grow at all, or but ill in it. By the experiments of Mr. Bergman, we find that

Argill takes up 2,5 times its weight of water when saturated so as to let none drop.

Magnesia - -	1,05
Chalk - -	0, 5
Silicious Sand -	0,25

* 1st Hales, 17.
† Mem. Par. 1748.

FIXED AIR.

That plants do not thrive, but most frequently perish, when surrounded by an atmosphere of fixed air, has long been observed by that great explorer of the most hidden processes of nature, Doctor Priestly ; but that fixed air imbibed by the roots is favourable to their growth, seems well established by the experiments of Doctor Perceval, of Manchester, and fully confirmed by those of Mr. Ruckert. This last-mentioned philosopher planted two beans in pots of equal dimensions filled with garden-mould. The one was watered almost daily with distilled, the other with water impregnated with fixed air, in the proportion of half a cubic inch to an ounce of water ; both were exposed to all the influences of the atmosphere, except rain. The bean treated with aerated water appeared over ground nine days sooner than that moistened with distilled water, and produced 25 beans ; whereas the other pot produced only 15. The same experiment was made on stock-July-flowers, and other plants, with equal

success*. The manner in which fixed air acts in promoting vegetation, seems well explained by Mr. Senebier: he first discovered that fresh leaves exposed to the sun in spring-water, or water slightly impregnated with fixed air, always produce pure air as long as this impregnation lasts; but as soon as it is exhausted, or if the leaves be placed in water out of which this air has been expelled by boiling, they no longer afford pure air†: from whence he infers that fixed air is decomposed, its carbonic principle retained by the plant, and its pure air expelled. It appears to me, also, by acting as a stimulant, to help the decomposition of water. Mr. Hassenfraz, indeed, denies its decomposition; but his arguments do not appear to me conclusive, for reasons too tedious and technical to mention here. The vitriolic acid contained in various clays brought into multiplied contact with calcareous earth by the agitation of soils in agricultural operations, and the motion of the roots, gradually sets loose the fixed air contained in this last-mentioned earth; that portion also of this earth, which is by water introduced into the plant, is decomposed,

* 2d Chym. Ann. 1788. 399.

† Sur l'Influence de la Lumiere, & 41 Rosier, 206.

and its air set loose by the vegetable acids of the plant.

OF SALINE SUBSTANCES.

Saline substances (gypsum and phosphorated calx excepted) seem to serve vegetables (as they do animals) rather as a *condimentum*, or promoter of digestion, than as a *pabulum*. This idea is suggested by the smallness of their quantity, and the offices they are known to perform. Their quantity is always smaller than that of earth; and this we have already seen to be exceeding small.

Thus one thousand pound of	lb.
Oak gives of saline matter only	1,5
Elm	3,9
Beech	1,27
Fir	0,45
Vine branches	5,5
Fern	4,25
Stalks of Turkey wheat	17,5
Wormwood	73
Fumitory	79
Trifolium pratense	0,78
Vetches*	27,5
Beans with their stalks*	20

* 3 Ruck. 49.

In all the experiments hitherto made, the proportion of saline matter to the earthy has been found smallest in woods. In other plants, generally as 1 to 1,3, 1,5, or 2; however, Mr. Ruckert has marked some exceptions, which I shall mention as worthy of notice.

PROPORTION OF SALINE SUBSTANCES TO THE EARTHY.

In Hemp	-	as 1	to	8.
Flax	- -	1	to	1,7 nearly
Parsnips	-	1,1	to	1.
Potatoes	-	1	to	1,3
Turnips	-	1	to	3,33
Wheat	-	1	to	3.
Rye	- -	1	to	8.
Oats	- -	1	to	8.

These proportions have some analogy with the quantity and sort of manure proper to be employed in the cultivation of these plants and the succession of crops. But I shall enter no farther into this subject as it would lead me too far from the present object of enquiry.

The salts generally extracted from the ashes of vegetables, are tartar vitriolate,

Glauber's salt, common salt, salt of Sylvius, gypsum, phosphorated calx, and fixed alkalis.

Alkalis seems to be the product of the vegetable process, for either none or scarce any is found in the soils, or in rain-water, while in the vegetable they are, most probably, neutralized, partly by vegetable acids which are decomposed in the process of combustion, and partly by the vitriolic and marine acids. Westrumb found tartar vitriolate and digestive salts in the juices of trifolium.

Gypsum probably exists in greater quantity in plants than it appears to amount to after combustion and lixiviation; much of it must be decomposed during the combustion, and still more during lixiviation, by the alkalis existing in the solution. Thus the apparent quantity of tartar vitriolate is increased.

Phosphorated Calx is found in greatest quantity in wheat, where it contributes to the formation of the animal gluten. Hence in rainy years the quantity of gluten in wheat has been observed to be smaller.* Hence the excellence of bone-ashes as a manure for wheat; and hence wheat

* 2d Witwer's Dissertations, 103.

succeeds best after clover, if the clover be fed off, but not if it be mowed,* as much of the phosphoric acid is communicated by the dung of animals.

The chief use of tartar vitriolate seems to be, that it promotes the decomposition of water, as Mr. Senebier has observed†.

* 2d Young's Annals, 36, 37.
† Sur la Lumiere, p. 130.

SECTION II.

OF THE CONSTITUTION OF FERTILE SOILS, AND THE METHOD OF ESTIMATING THEIR FERTILITY.

The most fertile soil is that which contains the greatest quantity of the food of those vegetables that nourish men and useful animals, and administers it to them with due economy.

The first essential requisite, therefore, to a fruitful soil is, that it contain a sufficient quantity of the three or four simple earths above mentioned, and of the soluble carbonaceous principle. The other requisites are, that the proportion of each, and general texture of the soil be such as to enable it to admit and retain as much water as is necessary to vegetation, and no more.

Now we have already seen, that the retentive powers of moisture are very different in the simple earths: therefore the proportions in which the fertility of a soil requires them to be mixed, must be different in climates and countries that differ

considerably in moisture: in the *drier*, they must be such as are most retentive: in the *moister*, such as suffer it to pass or evaporate more easily.

The same remark extends to situation. Lands on a plain should be so constituted as to be less retentive of water than those situated on a declivity; as is very evident.

So lands that have a retentive or impermeable sub-soil, should be differently constituted from those that have one less retentive or more permeable. The time of the year in which rain most abundantly falls may also be worthy of notice.

These circumstances must, undoubtedly, modify the conclusions that may be drawn from the experiments I shall now relate.

ANALYSIS OF A FERTILE SOIL IN A VERY RAINY CLIMATE.

Mr. Giobert has communicated to the public, the analysis of a fertile soil in the vicinity of Turin, where it rains yearly above 40 inches on the square foot. He found 1 lb of it to contain from 20 to 30 grains of extractive matter which flamed

and burned, and therefore was a coal soluble in water; 26 lb. of it contained 1808 grains of water. The simple earths were in the following proportion per cwt.*

Silex, from	—	77 to 79
Argill	— —	9 — 14
Calx	— —	5 — 12

Hence the pound should contain,†

		grs.
Carbonic matter	—	25
Water —	— —	70
Silex, from 4362		to 4475
Argill — 509	—	793
Calx — 283	—	679

He also found it to contain a great deal of air (about 19 grains) of which one-third was fixed, and the remainder heavy inflammable air: but no volatile alkali.

The weight of a cubic foot of this soil does not appear, nor is its specific gravity given; hence neither its texture, nor the quantity of each ingredient, can be directly ascertained; yet, from the necessity

* Encyclop. *Vegetation*. 276.

† The Turin medicinal pound is divided like the troy, and contains the same number of grains.

of its being, in some degree, open, and the weights of good soil found by Mr. Fabroni,* I conclude its specific gravity cannot exceed 1,58: then a cubic foot of it should weigh about 120 lb. troy, or 100 avordupois.

In less fertile soils, Mr. Giobert found the proportions of

Silex, from	48	to	80
Argill —	7	—	22
Calx —	6	—	11

Hence the troy pound contained, of

Silex, from	2716	to	4528
Argill —	396	—	1245
Calx —	339	—	662

allowing 100 grains for moisture, as either the calx or argill exceeds the proportions in more fertile lands.

The specific gravity of these soils is not given; but it probably exceeds or falls short of that of the more fertile soils.

* 8 Young's Annals, 174.

IN BARREN SOILS,

The proportions of Silex, from 42 to 88
Argill — 20 — 30
Calx — 4 — 20

Hence the troy pound contained, allowing for water 120 grains,

Silex, from 2368 to 4963
Argill — 1128 — 162
Calx — 225 — 620

The specific gravity of these soils is not given; but it probably is either much above or much below that of the former, as they are either too close or too open. Mr. Fabroni found that of barren sandy land 2,21.

Note also, that if the proportion of water be different from that here supposed, the contents of the troy pound will also be different; but may be easily rectified.

ANALYSIS OF A FERTILE SOIL, WHERE THE FALL OF RAIN IS 24 INCHES.

Mr. Bergman found that a fertile soil, situated on a plain, where the yearly fall of

rain amounts to 15 Swedish (that is 23,9 English) inches contained four parts clay, three of silicious sand, two of calcareous earth, and one of magnesia (in all ten parts;) but the last not being of absolute necessity may be annexed to the calcareous.

The composition of the clay he does not expressly mention, but we may suppose it such as most frequently occurs, containing 66 per cwt. of fine silicious sand, and 34 of mere argill: consequently 0,40 of it contain nearly 0, 14 of mere argill: and 0,26 of fine silicious sand.

The silicious sand, mentioned by Mr. Bergman, is what we call gravel (consisting of stone from the size of a pea, or less, to that of a nut;) and thus he himself explains it.* This amounts to 30 per cwt.

Hence we may state the proportions thus:

Coarse Silex - - -	30	
Finer — - - -	26	
		56 parts
Argill — - - -	14	
Calx — - - -	30	
	100	

* 5 Bergman, 102, 103.

The use of the gravel is to keep the soil open and loose: a circumstance absolutely necessary, as I have before observed.

The specific gravity is not given, but should not much exceed, I suppose, 1,600. Muschenbroek found that of garden-mould 1,630. The carbonic matter was not known to Mr. Bergman.

The proportion in a troy pound, supposing the quantity of water and coal not to exceed 100 grains, stands thus, omitting fractions:

Gravel - -	1698	
Fine Sand - -	1471	
		3169
Argill - - -		792
Calx - - -		1698

Here we see the quantity of calx much greater than in the soil of Turin, where the fall of rain is greater: for in the drier climates there is a necessity to retain the rain, and the argill if increased would retain it too long and too much; and, besides enters very sparingly into the constitution of plants.

The following experiments were made by Mr. Tillet, at Paris, where the fall of rain amounts to 20 inches at an average.

He filled with mixtures of different earths a number of pots twelve inches in diameter at the top, ten at the bottom, and seven or eight deep. It appears also, that they were so porous as to absorb moisture, and that they were perforated at the bottom. These he buried up to the surface in a garden, sowed in each some grains of wheat, and then abandoned them to nature.

FERTILE MIXTURES.

1st. The first mixture he found fertile, consisted of three-eighths of the potters clay of Gentilly=0,375, three-eighths of the parings of lime-stone, and two-eighths of river sand = 0,25. In this, the corn grew very well for three years; that is, as long as the experiment lasted.

As potters clay is not pure argill, and as Mr. Tillet does not mention the proportion the mere argillaceous part bore to the silicious, I must supply this defect, by supposing this clay to contain near one half of its weight of pure argill, as it is clay of this sort that potters generally chuse; and that of Gentilly is esteemed one of the best. Both the clay and lime-stone, he tells us, were pulverized, that they might

more exactly incorporate when mixed. Then the centesimal proportions will stand thus:

Coarse Silex	- -	25
Finer —	- -	21
		46
Argill —	- -	16,5
Calx —	- -	37,5
		100

The quantities in the troy pound, supposing the water, &c. to amount to 100 grains, are,

Coarse Sand	- -	1415
Finer —	- -	1188
		2603
Argill —	- -	934
Calx —	- -	2122
		5659

2d. This contained two-eighths of potters clay, three-eighths parings of lime-

stone, and three-eighths coarse sand. The centesimal proportions are,

Coarse Sand - -	37,5	
Finer — - -	14	
		51,5
Argill — - -		11
Calx — - -		37,5
		100

In the troy pound, supposing the quantity of water to amount to 100 grains, the quantities of the three earths will be,

Coarse Silex - -	2122	
Finer — - -	792	
		2914
Argill — - -		622
Calx — - -		2122
		5658

Hence we see that in the drier countries, where the fall of rain is but 20 inches, the soil, to be fertile, must be closer, and the quantity of calcareous earth much increased, and that of the silicious much

diminished. Thus, in the climate of Turin, where the fall of rain exceeds 40 inches, the proportion of silicious earth is from 77 to 80 per cwt. and that of calcareous, from 9 to 14, to suffer this excess of rain more easily to evaporate. In the climate of Upsel, where the fall of rain is 24 inches, the proportion of silex is only 56 per cwt. but that of calx is 30 ; and in the climate of Paris, which is still drier, the proportion of silex is only from 46 to 51, and that of calx 37,5 per cwt. and hence we may perceive the necessity of attending to the average quantity of rain to judge of the proper constitution of fertile lands on fixed principles. The quantity of rain differs much in different parts of the same kingdom ; but in general in Ireland, I believe it to be between 24 and 28 inches on an average.

In the two last mixtures the proportions vary considerably : The first may serve as a model for the heavier soils, and the second for the lighter. In these and the following experiments, the carbonic principle seems to have been extracted from the surrounding garden-mould with which the pots communicated, by means of their perforation, at bottom.

BARREN MIXTURES.

FIRST.

Mr. Tillet, in his sixth and eighth experiments, mixed three-eighths of potters clay with three-eighths of parings of limestone and two-eighths of *fine* sand; the only difference between this mixture and that of the first experiment was, that in the first experiment *coarse sand* was used, and in this *fine*, yet the former was fruitful in the highest degree; but in this the grain prospered indeed the first year, but sickened in the second, and failed in the third: the proportions have been already stated. Here we have a clear proof of the necessity of an open texture in soils, without which the best proportions are useless.

SECOND.

In his thirteenth experiment he employed a mixture of two-eighths potters clay, four-eighths coarse sand, and two-eighths marl. The corn grew well the first year, poorly the second, and decayed the third.

The composition of the marl is not mentioned; but supposing it to contain 70 per cwt. of calx, and 30 of clay, of which the one-half is argill, it would form one of the richest sorts of marls. The centesimal proportions of this mixture should be,

Silex	- -	50×14=64
Argill	- -	11× 8=19
Calx	- -	- 17
		× 100

And in the troy pound, supposing the water, &c. to amount to 100 grains, the quantities will be,

Silex	- -	3622
Argill	- -	1075
Calx	- -	962
		5659

The sterility of this mixture seems to proceed from a defect of calcareous earth. If we suppose the marl poorer in that earth, the defect will be still greater. The retentive powers of the different earths

with respect to water, being expressed by the quantities which each can retain without suffering any to drop, as above said, and the quantities retained by the mixed mass of these earths being proportional to the respective quantities of each, it should seem that in fertile soils, where the fall of rain is from 20 to 30 inches, this power should not exceed 70, nor fall short of 50 per cent. It were of great consequence to settle this point with precision; but to do this would require more numerous experiments. To explain my meaning, I shall give one example.

Of the retentive Power of the Fertile Soils, mentioned by Mr. Bergman.

This soil contains, as we have already seen,

Silex	-	56
Argill	-	14
Calx	-	30

Now the retentive power of 100 parts

Silex	=	25
Argill	=	250
Calx	=	50

Consequently the retentive power of

56	parts	Silex	=	13
14	-	Argill	=	35
30	-	Calx	=	15
				63

The constitution of the Irish fertile soils has not been ascertained, nor has the average annual quantity of rain been determined here. Indeed, the solution of the question proposed by the Academy, does not strictly require it should, not having been limited to any particular country: but I should suppose its best soil to approach to the nature of that of Upsal, the fall of rain being probably between 24 and 28 inches. In 1792, which was reckoned remarkably wet, it was 30½ inches in Dublin.

Before I quit the experiments of Mr. Tillet, it will be proper to mention a few made by him, which seem to invalidate the necessity of the presence of the three simple earths in fertile soils.

1mo. In his 26th experiment he tells us, he employed only pure sand, such as is used for making glass, yet corn grew well in it the first year, indifferently the second, and nearly failed in the third. Mr. Hassenfraz having repeated the experiment in pots unperforated, did not find it to succeed even the first year, therefore, the success of Mr. Tillet was owing to the perforation at the bottom of his pot, through which water, impregnated with the different earths, and coal must have

passed. In fact, Mr. Tillet's conclusion is contradicted by universal experience.

2°. In his 28th experiment, in which powdered lime-stone only was employed, the corn sown prospered exceedingly during the three years. To the cause mentioned, in treating of the 26th, I must add, that the lime-stone he used was that of St. Leu, which contains clay, and consequently silex and argill; it is so porous as to admit from 3-19ths to 1-5th of its weight of water, as Mr. Brisson has shewn; and thus is easily decomposed. The coarse powder to which it was reduced answered the same purpose as coarse silex; and the finer might nourish the plants.

3°. In his 30th experiment he employed mere potter's clay; the grain grew tolerably well the first year, but perished the second; on the third it flourished most. It is hard to draw any specific conclusion from this experiment, for it is plain that if the texture were not much looser than that of clay, the corn could not grow at all, as was the case in his 6th and 8th experiments, already mentioned, and as Mr. Hassenfraz, who repeated this experiment, observed. Rain-water might however supply a small quantity of calx sufficient for a small produce of corn.

I pass over his experiments on old mortar, as the three earths were evidently contained in it, though in unknown proportions.

Soils on the declivity of hills ought to be more retentive of water than those on plains as is evident.

CHAP. III.

TO DETERMINE THE COMPOSITION OF A SOIL.

1mo. IN dry weather, when the soil is not over moist nor dry, let a surface of 16 square inches be cut through to the depth of 8 inches; this may be effected by a right angled spade, formed for this particular purpose. Of the parallelopiped thus dug up, the two inches next the surface should be cut off to get rid of the grass, and the greater part of the roots; we shall then have a solid 6 inches long, and 16 square at the end = 96 cubic inches. Let this be weighed;* its weight will serve to find the specific gravity of the soil; for if 96 cubic inches weigh n pounds, 1728 (a cubic foot) should weigh x pounds, and x divided by 75,954 will express by the quotient the specific gravity of the soil. To render this and the subsequent operations more

* Troy weights are generally more exactly made than avoirdupois, and therefore should be preferred. A cubic foot of pure water weighs 75,945 troy, very nearly, or 62,5 avoirdupois pounds, at the temperature of 62°.

intelligible, I should illustrate each by an example: Suppose the 96 cubic inches to weigh 6,66 pounds, then 1728 cubic inches should weigh 120 lb. and $\frac{120}{75,945} = 1,579$.

2°. The earth being weighed, is next to be broken down and freed from all stony substances above the size of a pippin, and the remainder well mixed together, to render the whole as homogeneous as possible; then weigh the stones that were picked out, and find the proportion belonging to each pound of the residuary earth; call this the *stony supplement*, and denote it by *S*. Thus if the stones weigh 1 lb.=12 oz. the remainder, or mere earth, must weigh 5,66 lb. and if to 5,66 lb. there belong 12 oz. of stone, to 1 lb. must belong 2,12014 ozs. or 2 ozs. 57,66 grains = 1017,66 grs. This then is the stony supplement of each succeeding pound = *S*.

3°. Of the earth thus freed from stony matter, take 1 lb.—*S*. (that is the above case 1 lb.—2 oz. 57 two thirds grs.) heat it nearly to redness in a flat vessel, often stirring it for half an hour, and weigh it again when cold. Its loss of weight will indicate the quantity of water contained in 1 lb. of the soil. Note this loss, and

call it the *watery supplement=W*. Suppose it in this case 100 grains.

4°. Take another pound of the above mass freed from stones, deducing the stony and watery supplements; that is 1 lb.—S—W, or in the above case 1 lb.—2 oz. 57 two-thirds grs. for stone, and—100 grains for water; consequently 1 lb.—2 oz. 157 two-thirds grs. reduce it to powder: boil it in four times its weight of distilled water for half an hour; when cool, pour it off, first into a coarse linen filtre to catch the fibrous particles of roots, and then through paper, to catch the finer clayey particles diffused through it: set by the clear water, add what remains on the filtre to the boiled mass: if it be insipid, as I suppose it to be, then weigh the fibrous matter, and call it the *fibrous supplement=F*. Suppose it in the example in hand to weigh 10 grs.

5°. Take two other pounds of the mass freed from stony matter, No. II. subtracting from them the weight of the stony, watery, and fibrous substances already found; that is, 2 lb—2 S—2 W—2 F; pour twice their weight of warm distilled water on them, and let them stand twenty-four hours or longer; that is, until the water has acquired a colour; then pour it off,

and add more water as long as it changes colour; afterwards filtre the coloured water and evaporate it to a pint, or half a pint; set it in a cool place for three days, then take out the saline matter, if any be found, and set it by.

6°. Examine the liquor out of which the salts have been taken; if it does not effervesce with the marine acid, evaporate it to dryness, and weigh the residuum; if it does effervesce with acids, saturate it with the vitriolic or marine, and evaporate it to one fourth of the whole; when cool, take out the saline residuum, evaporate the remainder to dryness, and weigh it: this gives the coaly matter, which may be tried by projecting it on melted nitre, with which it will deflagrate. The half of this coaly matter call the *coaly supplement* of 1 lb. I shall suppose it to amount to 12 grs. and denote it by *C*.

7°. The filtred water, No. IV. is next to be gently evaporated to nearly one pint, and then suffered to rest for three days in a cool place, that it may deposit its saline contents, if it contains any; and these being taken out, the remainder must be evaporated nearly to dryness, and its saline and other contents examined. How this

should be done, I shall not mention, the methods being too various, tedious, and of too little consequence: few salts occur except gypsum, which is easily distinguished. The water may be examined as to its saline contents when it is evaporated to a pint; if any salts be found, call them the *saline supplement*, and denote them by *S*. I shall suppose them here = 4 grains.

8°. We now return to the boiled earthy residuum, No. IV. which we shall suppose fully freed from its saline matter, as, if it be not, it may be easily rendered so, by adding more hot water: let it then be dried as in No. III. is mentioned. Of this earthy matter thus dried, weigh off one ounce, deducting one-twelfth part of each of the supplements *S. W. F. C.* and *S'*; that is, in this case

$$\frac{1017,66}{12} = 84,405 + \frac{100}{12} = 8,333 + \frac{10}{12} =$$

$$8,333 + \frac{12}{12} = 1 + \frac{4}{12} = 0,3333 = 95 \text{ grs. in all}$$

—then 480—95=385 grains will remain, and represent the mere earthy matter in an ounce of the soil.

9°. Let this remainder be gradually thrown into a Florence flask, holding one

and an half as much spirit of nitre as the earth weighs, and also diluted with its own weight of water (the acids employed should be freed from all contamination of the vitriolic acid;) the next day the flask with its contents being again weighed, the difference between the weights of the ingredients and the weights now found, will express the quantity of air that escaped during the solution. Thus, in the above case, the earth weighing 385 grs. the acid 577,5 grs. and the water 577,5 grs. in all 1540 grs. the weight after solution should also be 1540, if nothing escaped; but if the soil contains calcareous matter, a loss will always be found after solution. Let us suppose it to amount to 60 grains.

The weight of air that escaped, furnishes us with one method of estimating the quantity of calcareous matter contained in the earth essayed; for mild calx generally contains 40 per cent. of air; then if 40 parts air indicate 100 of calcareous matter, 60 parts air will indicate 150.*

10°. The solution is then to be carefully poured off, and the undissolved mass washed and shaken in distilled water; the whole

* I take no account of magnesia, as in agriculture I believe it of little importance.

thrown on a filtre, and sweetened as long as the water that passes through has any taste. The contents of this water should be precipitated by a solution of mild mineral alkali: this precipitate also being washed and dried in a heat below redness, should then be weighed. Thus we have another method of finding the weight of the calcareous matter.

11°. The undissolved mass is next to be dried in the heat already mentioned, and the difference between its weight and the weight of the whole earthy mass before solution should be noted, as it furnishes a third method of discovering the weight of the calcareous matter of which it is now deprived. Supposing this to amount to 150 grains, the weight of the undissolved residuum should in the above case be 383 —150=235 grains.

12°. Reduce the dried mass into the finest powder, throw it into a Florence flask or glass retort, and pour on it three times its weight of pure oil of vitriol, digest in a strong sand heat, and at last raise the heat so as to make the acid boil; afterwards let it evaporate nearly to dryness: when cold, pour on it gradually six or eight times its weight of distilled water,

and, after some hours, pour off the solution on a filtre; the filtre should previously be weighed, and its edges soaked in melted tallow;* the substance found on the filtre being weighed (subtracting the weight of the filtre) gives the quantity of silicious matter; and this weight subtracted from that of the dried mass, gives that of the argill. In this case I will suppose the silicious mass to weigh 140 grains, then the argillaceous should weigh 95 grains.

Then the composition of one pound of the soil is as follows:

Stony matter	-	1017,66
Water -	-	100
Fibres of roots	-	10
Soluble coal	-	12
Saline matter	-	4
Silex	$140 \times 12 =$	1680
Argill	$95 \times 12 =$	1140
Mild calx	$150 \times 12 =$	1800
		5763,66†

* An ingenious contrivance of Dr. Black.

† An error of 3,66 grains for decimals omitted in subtractions.

And in centesimal proportion	Stony matter	18	
	Fine silicious	29	
			47
	Argill		22
	Mild calx		31
			100

Its retentive power is 82,25 : hence I should judge it to be unfertile in this climate unless situated on a declivity, with an unimpeded fall. It may be called a *clayey loam*.

Mr. Young discovered a remarkable circumstance attendant on fertile soils : he found that equal weights of different soils, being dried and reduced to powder, afforded quantities of air by distillation somewhat corresponding to the ratios of their values. This air was a mixture of fixed and inflammable airs, both proceeding, most probably, from the decomposition of water by the coaly matter in the soil. The distillation should be made from a retort glazed on the outside. He found an ounce of dry soil, value five shillings, produced ten ounce measures ;

Of value of from	5 to 12s.	produced 28ozs.
	12—20	42
above	20	66

This appears to be a good method of estimating the proportion of coaly matter in soils that are in full heart; that is, not exhausted, and freed from roots, &c. Another mark of the goodness of a soil is the length of the roots of wheat growing in it; for these are an inverse proportion to each other, as, if the land be poor, the wheat will extend its roots to a great distance in quest of food; whereas, if it be rich, they will not extend above five or six inches; but of these and some other empyrical marks, I shall say no more, as they do not tell us the defects of the soils.

CHAP. IV.

OF THE MANURES MOST ADVANTAGEOUSLY APPLICABLE TO THE DIFFERENT SOILS, AND OF THE CAUSES OF THEIR BENEFICIAL EFFECT IN EACH INSTANCE.

THE solution of the first part of this problem can only be derived from general practice of the most skilful farmers, corrected, however, and improved by the more precise determinations and restrictions of theory. That of the second, I shall endeavour to deduce solely from the theory established in the two last chapters. The whole is grounded on this simple proposition—That *manures are applied to supply either the defective ingredients of a soil, or improve its texture, or correct its vices.*

I now proceed to consider each soil in particular.

OF CLAYEY SOILS.

The best manure for clayey soils is marl: in this all the books of agriculture are unanimous;* and of the different sorts of marl, that which is most calcareous is best; the silicious next best; limestone-gravel best of all; and argillaceous marl least advantageous.†

Clayey soils are defective both in constitution and texture; they want the calcareous ingredient and coarse sand. Calcareous marl supplies the calcareous ingredient chiefly: limestone gravel both. The other marls supply them in a lesser degree. If the clay be analysed, and its proportion of sand and argill known, the species of marl most advantageously applicable may be determined still better. For instance, if the argill notably exceeds or even amounts to the proportion of 40 or 50 per cwt. calcareous marl or limestone-gravel are the best improving manures, as they contain most of the calca-

* 4th Young's Eastern Tour, 404. 1st Body of Agriculture, 104, 108.

† Ibid, 108.

reous ingredient; but if the silicious ingredient amounts to 75 or 80 per cwt. as it sometimes does, argillaceous marl is most suitable.

A mixture of marl and dung is still more advantageous,* because the dung supplies the carbonaceous ingredient. But the marl must be used in the same quantity as if dung had not been applied, otherwise the operation must be more frequently repeated. How the quantity of marl or other manure can be estimated, I shall presently shew.

If marl cannot be had, a mixture of coarse sand and lime perfectly effete or extinguished, or chalk, will answer the same purpose, as it will supply the defective ingredient, and open the texture of the clay; so also sand alone, or chalk, or powdered limestone, may answer, though less advantageously. Lime alone appears to me less proper, as it is apt to cake, and does not sufficiently open the soil.

Where these manures cannot be had, coal ashes, chips of wood, burned clay, brick-dust, gravel, or even pebbles, are useful;† for all these improve the texture,

* 4th Young's Eastern Tour, 404.

† 5 Bergman, 107; and Young's Irish Tour, 129, 136. 249.

and the former supply also the carbonaceous ingredient.

Before I advance farther, to prevent superfluous repetition, I shall lay down a second general maxim: which is, That *dung is a proper ingredient in the appropriated manures of all sorts of soils*, as it supplies the carbonaceous principle.

OF CLAYEY LOAM.

This soil is defective either in the calcareous ingredient, or in the sandy, or in both: if in the first, the proper manure is chalk:* if in the second, sand; if in both, silicious marl or limestone-gravel, or effete lime and sand.

The quantity of chalk that should be employed, considered abstractedly, should be directly proportional to the defect of calcareous matter; but as such a quantity cannot be added without diminishing the proportion of one of the other ingredients, a much smaller quantity must be employed, or else a substance which may convey

* 1st Young's Eastern Tour, 395.

some proportion of the other ingredient. The same observation holds also with respect to sand. Thus we have seen, in the last chapter, a clayey loam, in which the sandy ingredient was defective, and the argillaceous superabundant, but the calcareous exact. Its composition stood thus :

Sand and Gravel - -	47
Argill - - - - - -	22
Mild Calx - - - -	31

Here the sandy part wants 10 per cwt. the argill is superabundant; but we cannot increase the proportion of sand without diminishing that of calx. Hence we must either use a smaller proportion of sandy ingredient than its defect requires, or apply a substance that would supply some proportion of the calcareous ingredient also: such are limestone-gravel, silicious marl, effete lime, mixed with sand, or pounded limestone. Suppose the proportion of the substance to be employed were six per cwt.; that is, six pound for every hundred pounds of the soil, then the quantity requisite for an acre may be calculated thus: a square foot of this soil, cut down to the depth of fourteen inches, and paring off the two up-

permost, as consisting chiefly of roots, &c. weighs, as we have seen, 120 lb. ; and if 100 lb. requires six of the manure, 120lb. will require 7,2; therefore every square foot of the soil will require 7,2 of the manure : now an English acre contains 43560 square feet; and consequently 43560 multiplied into 7,2 of the manure = 313632lb. or 208 cart loads, reckoning 1500 lb. to the cart load.

CHALKY SOILS.

This soil wants both the argillaceous and the stony, sandy, or gravelly ingredients; therefore the best manure for it is clayey loam, or sandy loam;* but when the chalk is so hard, as it frequently is in England, and so difficultly reducible to impalpable powder as to keep of itself the soil sufficiently open, then clay is the best manure,† as in such cases the coarse sand or gravelly ingredients of loams are of no use. Some think, it is true, that pebbles in a field serve to preserve or communi-

* 5 Bergman, 107.
† Young's Eastern Tour.

cate heat. This use, however, is not sufficiently ascertained.

CHALKY LOAM.

The best manure for this soil is clay, or argillaceous marl,* if clay cannot be had; because this soil is defective principally in the argillaceous ingredient. In Ireland, chalky soils or loams seldom occur, but light limestone soils frequently, and these do not differ essentially from chalky loams poor in argill: clay, therefore, and often the soil of bogs, should serve as a manure for them.

SANDY SOILS.

The best manure for these is calcerous marl,† which exactly corresponds with our theory; for these soils want both the argillaceous and calcerous ingredients; and this marl supplies both: the next best is argillaceous marl; and next to these, clay, mixed with lime, or calcareous, or clayey

* 4th Young's Eastern Tour, 404.
† Ibid. 401, 412.

loams. In Norfolk, they seem to value clay more than marl, probably because their sandy soils already contain calcareous parts; possibly, also, they misname marl, calling mere chalk by that name. Lime or chalk are less proper, as they do not give sufficient coherence to the soil; however, when mixed with earth or dung, they answer well,* because they form a sort of marl or compound, comprehending the defective ingredients.

SANDY LOAMS.

These are defective chiefly in the calcareous ingredient, and, in some degree, also in the argillaceous; their texture too is imperfect, as they abound both in fine and coarse sand; chalk or lime would supply the first defect, but would leave the texture unamended. Hence they are used when better cannot be had;† yet calcareous or argillaceous marls are most proper.‡ Clay, after land has been chalked, answers,

* Young's Eastern Tour, 397.
† 4th Young's Eastern Tour, 398.
‡ Ibid. 402.

as we are told, remarkably well, because it remedies the texture.*

GRAVELLY LOAMS.

These soils are benefited by the application of marl, whether argillaceous or calcareous,† for reasons which I suppose are now apparent: if the gravel be calcareous, clay may be employed.‡ A mixture of effete lime and clay should answer in all cases.

TILL AND VITRIOLIC SOILS.

These necessarily require the calcareous ingredient to neutralize their peccant acid: hence chalk, limestone-gravel, lime and calcareous marl, are most advantageously applied to them.

Home, 35.

BOGS, OR BOGGY SOILS.

When these are well dried by sufficient

* 4th Young's Annals, 413.
† 4th Young's Eastern Tour, 404, 406.
‡ 1st Eastern Tour.

drains, the nature of their soil should be explored by analysis, and an appropriate manure applied. In general, they should first be burned, if capable of that operation, then gravelled. If their upper parts contain a sufficiency of the carbonaceous principle, as often happens, they need not be burned. Limestone-gravel will answer best, or lime mixed with coarse sand or gravel, because in general they are of a clayey nature; if more sandy, lime may answer well, or calcareous marl. The preference in these cases must be decided by analysis.*

HEATHY SOILS.

These should first be burned, to destroy the heath and increase the carbonaceous principle: they should then be analysed, and the defective principles supplied. Lime is said to destroy heath, and so is limestone-gravel:† this is fittest when the soil is clayey; lime when it is gravelly.‡ Gypsum also answers remarkably well when the soils are dry.

* Young's Irish Tour, 233, 223.
† 4th Young's Eastern Tour, 396.
‡ Irish Tour, 212.

OF SOME PARTICULAR MANURES.

We have now stated most of the known soils, and mention the manures which tend most to their improvement: there are, however some others whose mode of action is not generally understood, and whose nature it will therefore be proper to explain.

OF PARING AND BURNING.

This mode of improvement is not particular to any species of soil, though poor soils that have few vegetables growing in them, will certainly profit least by it.

Its advantages are,

First, that it converts vegetables and their roots into coal. Hence it is that agricultural writers tell us, though without knowing the reason, that all violence of fire is to be avoided, and that a slow smothering fire is best.*

Secondly, That it destroys the old sickly roots, and thus leaves room for others younger and more vigorous.

* 1st Body of Agriculture, 210, 211.

Many have imagined that it diminishes and consumes the soil; but repeated experience has shewn the contrary. I need only mention that of Colonel St. Leger, in Yorkshire, related by Mr. Young in the 1st volume of his Eastern Tour, p. 182. It is well known that clays and loams are rather hardened than consumed by heat. However, unless fresh seeds be committed, the soil will be unproductive for a number of years; the coaly principle may also be exhausted by too many crops.

OF GYPSUM.

This manure was discovered by Mr. Mayer, a German clergyman of uncommon merit, in the year 1768: it has since been applied with signal success in Germany, Switzerland, France, and America.

If in England it has not been so much approved of, it must be because the calcareous principle prevails there almost universally: clayey lands are most improved by it. The time for spreading it is February or March, and then it is to be thinly strewed on the land at the rate of about eight bushels to the acre: more would be hurtful. The *rationale* of its

effects may be deduced from its extraordinary septic power, for it is found to accelerate putrefaction in a higher degree than any other substance;* and hence it is not ploughed in like other manures, but barely strewed on the surface of the land; and in the month of February, to convert the old grass quickly into coal, to nourish the young growth.

2dly. From its being itself no inconsiderable part of the food of many plants, particularly of clover, pulse, and corn, but the land on which it is strewed must be dry, such as would naturally suit clover, &c. otherwise it would be useless.

Thus far I have endeavoured to illustrate the important subject proposed by the Academy, collecting and reflecting upon it the scattered rays resulting from the latest chemical researches. The intimate connexion between many of these, seemingly the most abstract and remote, with the hidden process of nature, may now be clearly perceived. These grand and complicated operations, like a well fortified town, cannot be mastered by storm or a coup-de-main; the approaches must be made at a distance, and almost unseen.

* Histoire de la Putrefaction, 36.

Hence we may infer how little can be expected from agricultural societies that do not unite chemistry and meteorology with their principal object.

With respect to the question at present before us, the great desiderata seem to be, *How to render charcoal soluble in water for the purpose of vegetation:* and, *to discover that composition of the different earths best suited to detain or exhale the due proportion of the average quantity of moisture that falls in each particular country.* On this relation, or adaptation, we have seen that the fertility of each essentially depends: we must also have perceived, that to a regular and systematic improvement of soils, a knowledge of their defects, and of the *quantum* of their defects, is absolutely necessary. This information can be conveyed only by a chemical analysis. Country farmers (at least as long as the present absurd mode of education prevails) cannot be expected to possess sufficient skill to execute the necessary processess: but country apothecaries certainly may. The profit arising from such experiments (should the public encourage them) would sufficiently excite them to acquire a branch of knowledge so nearly allied with their profession. In the mean

time, soils might be sent to some skilful persons in the capital by country gentlemen; who would thus be enabled to ascertain and appreciate the advantages attending such researches, and enlighten and encourage their more ignorant and diffident neighbours. Many of them might, perhaps, themselves feel a taste for occupations of this nature: occupation swhich not only fully suffice to fill up the many vacant hours and days which the solitude of a country life must frequently leave them, but are, moreover, sweetened by the pleasing recollection, that, of all others, they tend most directly to the general happiness of mankind.

AGRICOLA.

THE END.

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